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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

INTERAGENCY REPORT
NASA-124
September 1968

Mr. Robert Porter
Acting Program Chief,
Earth Resources Survey
Code SAR - NASA Headquarters
Washington, D.C. 20546

Dear Bob:

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INTERAGENCY REPORT NASA-124

PRELIMINARY EVALUATION OF INFRARED AND RADAR
IMAGERY, WASHINGTON AND OREGON COASTS*

by

Parke D. Snavely, Jr.**
and
Norman S. MacLeod**

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Menlo Park, California 94025; and 601 E. Cedar Avenue, Flagstaff,
Arizona 86001.

Sincerely yours,

W.A. Fischer

William A. Fischer
Research Coordinator
EROS Program

*Work performed under NASA Contract No. W-12589 and
Task No. 160-75-01-54-10

**U.S. Geological Survey, Menlo Park, California

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Prepared by the Geological Survey
for the National Aeronautics and
Space Administration (NASA)

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Task No. 160-75-01-54-10

**U.S. Geological Survey, Menlo Park, California

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PRELIMINARY INTERPRETATION OF INFRARED AND RADAR
IMAGERY, WASHINGTON AND OREGON COASTS

by

Parke D. Snavely, Jr.

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Norman S. MacLeod

U.S. Geological Survey
Menlo Park, California

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PREFACE

This preliminary evaluation of the applications of infrared imagery to problems in marine geologic mapping (Task No. 160-75-01-54-10) is intended to serve as a Mission Analysis Report of NASA Convair 240, Mission 55 flown on August 16, 1967.

The images contained in this report are negative prints in which bright areas represent cool materials and black areas are relatively warm.

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Contents

	Page
Introduction	1
Infrared Imagery	2
Radar Imagery	7

Illustrations

- Figure 1. Infrared image of the mouth of the Quinault River, Washington.
- Figure 2. Infrared image of the mouth of the Queets River, Washington.
- Figure 3. Infrared image of the mouth of the Hoh River, Washington.
- Figure 4. Infrared image of wave-cut platform shoreline, near Ozette Island, Washington.
- Figure 5. Infrared image of large scale ripple marks, Willapa Bay, Washington.

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Introduction

This report summarizes the preliminary interpretation of infrared and radar imagery of parts of the Washington and Oregon coast. This coastal area is an ideal testing site for remote sensing techniques inasmuch as, in contrast to other imagery testing sites, it has a dense cover of vegetation and bedrock is poorly exposed. Thus it serves to define limitations of imagery in areas not ideally suited for geologic interpretation of conventional aerial photographs.

Much of the geology of this coastal area has been mapped as part of the U. S. Geological Survey's regional geologic mapping program. More recently, detailed investigations of the geology of the Oregon and Washington coast have been undertaken as part of the study of the stratigraphy, structure, economic potential and origin of the continental shelf extending from the continental margin to the Coast Ranges. Because much of the existing mapping of the coastal belt is reconnaissance, more detailed mapping of selected areas has been required for the interpretation of some features shown by the imagery. Field studies of most of these features will be completed by September, 1968, and a detailed report of the infrared and radar imagery will be prepared.

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INTRODUCTION

Infrared imagery of the Willapa and Cowlitz River coastal areas was acquired by a N.A.S.A. Recorotor IV R.R. Imagex photographic system in the 8 to 14 micron band. The images were obtained on August 10, 1967 between 1743 and 1815 hours from an altitude of 15,000 feet. Scale on the 70 mm film on which the imagery is recorded varies somewhat but in most areas is about 1:70,000; scale parallel to the flight path differs from that normal to the path resulting in slight distortion. Selected parts of the original imagery were enlarged 3.5 times for detailed analyses.

The coastal area shown in the infrared imagery is characterized by high annual rainfall and dense vegetation. Several rivers whose headwaters are in the Olympic Mountains discharge into the sea along the northern Washington coast; among the larger of these are the Soleduck, Hoh, Queets, and Quinault Rivers. The Chehalis, Willapa and the Columbia Rivers discharge to the sea in the southern coast through Grays Harbor, Willapa Bay and the Columbia estuary.

Lower Eocene to Pliocene sedimentary and volcanic rocks crop out on wave-cut platforms, sea cliffs, and rugged headlands between Grays Harbor and Cape Flattery along the Washington coast. Pleistocene glacial debris blankets most of the inland area and locally extends beyond the coast line. South of Grays Harbor to the Columbia River the coastal area is characterized by broad beaches, and spits that are mantled by dune deposits; Tertiary bedrock is exposed only in a few places.

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Surveys in the undifferentiated areas have been generally successful in areas where water so turbated the conductivity readings that no reliable data could be provided due to nonisotope marine processes. Preliminary observations from the imagery indicate that it is of little value for mapping to examine bedrock geologic features. Variations in rock lithology could not be discerned on the imagery nor could most structural elements such as large faults. A slight linear thermal anomaly is shown near Point Grenville over the trace of a large north-south running fault. It is very faint and would probably not have been noted had the presence of the fault not been known. It appears as a narrow band of slightly higher relative temperature extending from a raised terrace onto the adjacent beach, and probably is produced by discharge of relatively warm spring water along the fault trace.

Color aerial photographs of the coastal area, on the other hand, show geologic features such as bedding, lithologic contacts, and faults very clearly. Enhanced, false-color composites of an infrared image of a wide wave-cut platform on the coast near Ossette Island are now being prepared. These may enhance lithology-produced thermal variations not otherwise visible in the infrared imagery. An enhanced, false color composite of a color aerial photograph of this same area is also being prepared in order to provide an additional basis for comparison of infrared imagery and color aerial photographs.

Even though the infrared imagery has not been particularly useful in respect to showing bedrock features, it does show remarkable thermal variations in sea water adjacent to the coast. These are significant

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Water along 200 to 300 miles of coast between the Columbia River and the mouth of the Columbia River, Oregon, Washington, and British Columbia, is believed to be relatively free of thermal plumes.

Developed systems of warm surface waters exist, however, at the mouths of major rivers and the mouths of several smaller streams in the Quinault, Queets, Cowlitz, and Elwha Rivers, shown in figures 1, 2 and 3. The systems of warm water extend at least 7000 feet offshore, beyond the limits of available imagery, and are 5000 to 15,000 feet wide in the north-south direction. They are usually semicircular in shape and most are directed southward with respect to the river mouths due to longshore currents and (or) prevailing winds. They extend seaward from an area beyond the low tide line and are connected to the river mouths by a narrow belt of warm river water.

The internal structure of the aprons is complex. For instance, the apron off the Quinault River is composed of at least two impinging plumes, one of which appears older. The axis of the older Quinault plume, and also that of the much fainter of two plumes developed off the Queets River, is parallel to but located about 2500 feet from that of the younger plume. The individual plumes contain more than five pronounced concentric thermal bands. The outer limit of each band is sharp and contains relatively warm water; the water temperature within individual bands decreases rapidly landward. Small faint concentric bands occur within and parallel to borders of the larger bands.

These concentrically banded thermal plumes most likely formed as a result of pulsing discharge of fresh river water in dynamic

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influence of the river discharge on the thermal regime of the estuary. The effect of tidal range would be to increase the mixing of the river water with ocean water, so that the thermal regime would be more uniform. The influence of river discharge would depend on a number of factors related to the river discharge volume, or concomitantly with, and to the timing, magnitude and duration cycle. Discharges would continue the thermal cycle with varying amplitude just as before, or with, large differences. The magnitude of change in mid-August, assuming mean river discharge minimum and freshwater discharge constant, the longitudinal branch at high tide could be small or nonexistent. The change was greater during a rising tide at the time when fresh-water discharge would tend to be impounded by the rising salt water offshore, as shown by a rising dam. Such behavior would be comparable with the distinctly sharp edges of the fresh-water plume as it flows offshore, close inshore. On a falling tide, the impounded fresh-water would tend to be freed so that a "feathered" edge to the thermal bands would be expected. Fresh river water would tend to float above ocean water, both offshore and in the estuarine reach of the river, due to density difference accentuated by thermal and dissolved-solid differences. Except in the surf zone, movement of water is much closer to laminar than turbulent, so that mixing and diffusion are relatively slow.

Several infrared images made at about 2 hour intervals between high tides would provide the data needed to interpret plume origin.

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GOALS: To identify and delineate areas of wave-cut platforms, sand waves, and other features which may be related to wave action.

METHODS: Infrared imagery was used to delineate wave-cut platforms, sand waves, and other features which may be related to wave action.

RESULTS: On both the North and South Oregon Coast, wave-cut platforms and sand waves were found to be closely related to prevailing winds. They may also provide some clue as to the direction of suspended sediment within the surf zone. Such data would be very useful for the interpretation of bathymetric topography and current meters.

Several other water features are shown by the infrared imagery. A wave agitated belt 300 to 1500 feet wide immediately adjacent to the coast where no wave-cut platforms are present is shown by a series of complex thermal patterns. The width of this belt provides a measure of the dispersal of beach sediment by wave action. Discharge of warm water from probable fresh water springs near the edge of wave-cut platforms is shown by the infrared images between Sand Point and Cape Alava, Ozette quadrangle, and in several other places on the Washington coast (Figure 4). Cuspate thermal patterns around reefs, small islands, and headlands show the direction of net transport of surface water as a result either of longshore currents or prevailing winds. Thermal eddies in surface waters of small coastal embayments are shown in the imagery and result from topographic interference with surface water transport.

Large-scale rhomboid ripples show in the infrared imagery in Willapa Bay (Figure 5). The ripples have wave lengths of about 200 feet and have superimposed sand waves which trend normal to the rhomboid

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ripples. Both wave forms are probably the result of rapid sheet flow on tidal flats during outgoing tide. After these features are investigated in the field they will be reported upon more fully.

Radar Imagery

Preliminary interpretation of radar imagery of a 10 miles wide strip of the Oregon Coast extending from the California border to the Columbia River is reported in Snavely and Wagner (1966). Since submittal of that report, field evaluations of the radar imagery have continued but, because of the large area involved, are not yet complete. Principal conclusions presented in the technical letter are: (1) radar imagery provides a very clear rendition of the topography and in essence "defoliates" the thick cover of vegetation; (2) rocks of high density and surface roughness underlie areas depicted on the imagery with light tones, and rocks with low density and (or) high water content underlie areas which appear dark on the imagery; and (3) fault traces can be discerned on the imagery by juxtaposition of areas with different tonal rendition and by associated linear topographic features.

Reconnaissance field mapping during the last year has shown that several anomalous linear features on the imagery are expressions of previously unrecognized faults. The largest of these faults trends northeast from near the mouth of Drift Creek (south of Lincoln City) for a distance of at least 10 miles and is expressed on the radar imagery as an aligned series of hills and streams. Field investigations

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have shown that several other similar linear features on the radar imagery, however, result from topographic expression of particularly resistant beds. Therefore, careful field investigations are a prerequisite to geologic evaluation of the radar imagery.

Additional field work including detailed ground and aeromagnetic surveys are planned during the summer of 1968 on an arcuate volcanic structure, described in Snavely and Wagner (1966) which occurs 10 miles south of Astoria. It is anticipated that the investigations of this structure and field studies of other structural elements shown on the radar imagery will be completed during the summer of 1968 and a comprehensive report on the geologic evaluation of the radar imagery will then be issued.

Reference Cited:

Snavely, P. D., Jr., and Wagner, H. C., 1966, Geological evaluation of AN/APQ-97 radar imagery, Oregon coast: U. S. Geol. Survey Tech. Letter NASA-16, 7 p.

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Figure 1. Enlarged infrared (8 to 14 μ) image of mouth of Columbia River, Taholah, Washington. Two plumes of relatively warm river water spread seaward from near river mouth. Note the well defined thermal bands with sharp outer margins and gradual inward decrease in relative temperature. Sand bar is present on south side of river mouth. Rectangular light areas north of river are logging tracts. Distance from bridge to river mouth is about 3600 feet.



Figure 1.

Figure 2. Infrared (8 - 14 μ) image of mouth of Quetico River.

Thermally banded plume extends southward from river mouth. Faint older plume is visible immediately to left, and concentric to, river mouth. Marshy area (light) on southwest extension river below bridge probable is former river channel. Distance from bridge to river mouth is 5,600 feet.



Figure 2.

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Figure 3. Infrared (8 to 14 μ) image of mouth of Rob River showing banded thermal plume. Banded pattern is elongated adjacent to coast by wave-agitation. Distance from river mouth to right hand margin of image is 3,000 feet.



Figure 3.

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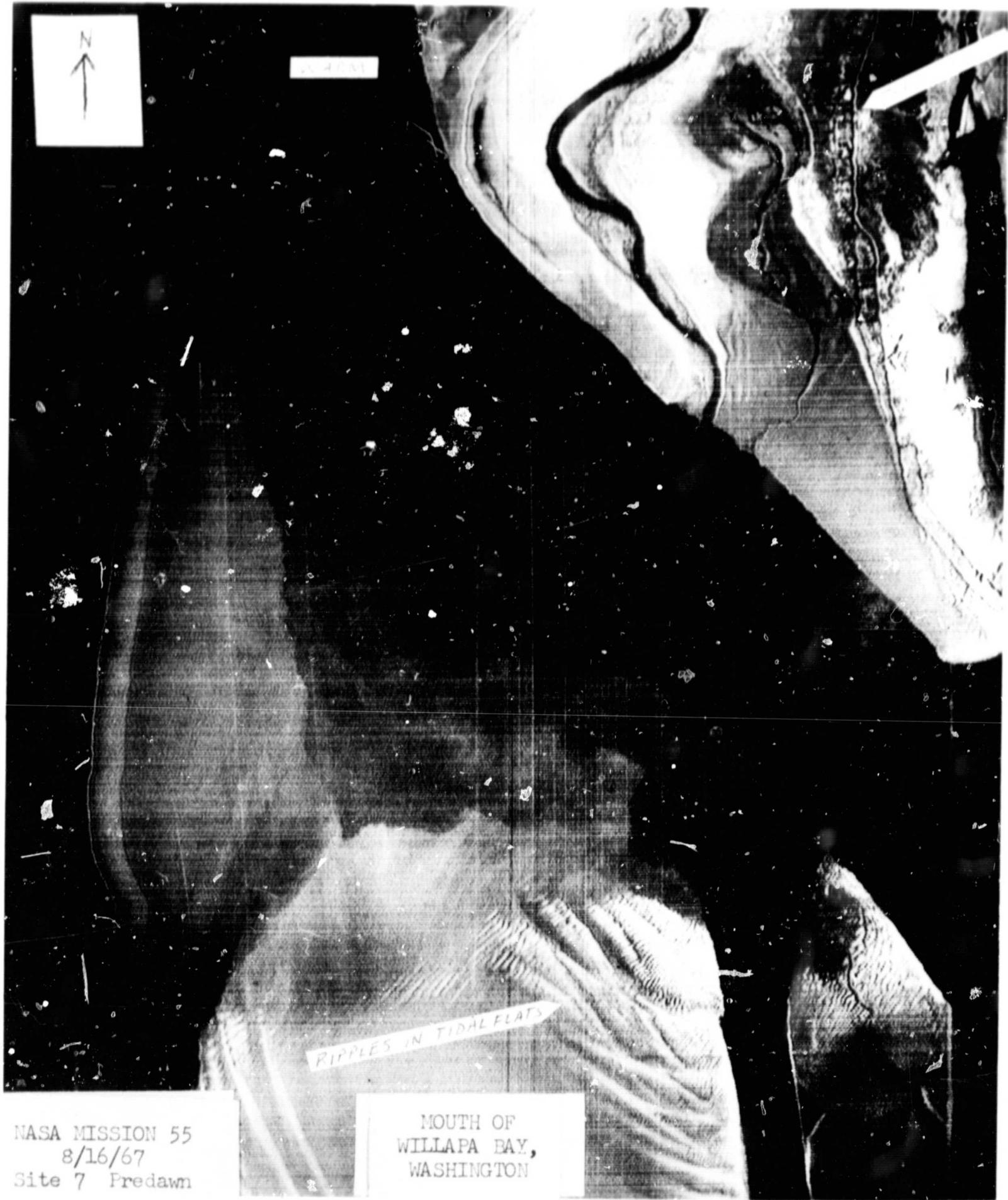
THESE PICTURES ARE OF THE SAME AREA AS
THOSE ON THE PREVIOUS PAGE.
PHOTONIC SUBSTRATE SURFACE AND POLYMER
LAYERED TO SHOW FEATURES WHICH ARE NOT
VISIBLE (WATER GROOVES) THESE FEATURES SHOW THE SURFACE
AND STRUCTURE OF POLYMER WHICH IS DIFFERENTLY
EVIDENT IN THIS AREA AND ARE ENHANCED BY THE
ENHANCED IMAGES.



Figure 4.

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காலத்திலே குறிப்பிட்டு வரும் சம்பந்தமாக அதை விரிவாக விவரிதிப்பது முன் கூறுவது என்று சொல்லப்படுகிறது.



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WILLAPA BAY,
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Figure 5.